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Experimental study on metal corrosion in soil environment of Cross Rivers State of Nigeria

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ABSTRACT
Investigation was conducted in some communities of Cross Rivers State to experimentally examine the effect of soil characteristics on metal corrosion in different soil environment of clay, swampy and sandy. Soil samples were collected from the following zones located in Cross Rivers State Ejajam, Yala and Ikot Nnakanda and different metal specimen were immersed in the soils as to study the effect of the soil physicochemical parameters on metal corrosion. The weight loss on each metal sampled was determined and the corrosion rate equation was applied to calculate the rate of metal corrosion on each of the metal specimen. The result obtained reveals the significant effect of the soil characteristics on the metal in terms of weight loss as well as rate of corrosion. The result revealed the period of exposure increases the rate of corrosion, weight loss of the metal increase as well with variation in the physicochemical parameters of the soil. The physicochemical parameters considered in this research work are pH, electrical conductivity, density, moisture content, dissolved oxygen, chemical oxygen demand, temperature, total dissolved solid as well as the microbial activities. The research work demonstrates the effect of soil characteristics on metal corrosion.

Keywords: Experimental, study, metal, corrosion, soil environment, Cross Rivers State, Nigeria

1. INTRODUCTION

The weight loss approach involves the concept of exposing a specimen of metal materials to the corroding environment for a given period as well as the process of removing the specimen for purpose of weighting to examine the loss in weight of the initial material weight. The weight loss or gain is taken over the period of exposure and later expressed as a corrosion rate [1]. The determination of weight loss of a material in a corrosion experiment has been one of the common methods used to calculate corrosion rate [2]. The weight loss approach is used to as to enable the corrosion rate measurement to be done without disturbing the plant operation [3]. Corrosion of metal has been studied by various research groups and problems associated inducing the challenges are well considered. The interaction of physiochemical parameters in the different environment considered in this research work will be used in predicting the other Niger Delta area soil and water media [4-6]. The metal corrosion prediction parameters are a major problem in Nigeria, because the accurate machine of metal as a result of corrosion prediction cannot be ascertained and the required information on the behaviors of the environment is unknown. It is only when corrosion is experienced or detected that maintenance can be carried out as well as investigation also conducted to examine the root cause of the problem [7-9].

In carrying out the investigation, one of the major challenges can be attributed to lack of equipment as well as the difficulty to get all required information that could have helped in detailed reporting of the investigation [10]. The significance for this work is hinged on the need to contribute to an increasing wealth of knowledge on the role of microorganisms and physicochemical parameters in influencing corrosion rate of metals [11]. The uniqueness of this work is based on the fact that previous investigations on corrosion were centered on one type of environment, mainly laboratory studies with less or no attention paid to corrosion process in the natural environments, using finite element approach to examine the process involved in metal corrosion resulting from weight lost. The psychochemical parameters played a vital role in metal corrosion as well as the interaction or these parameters influence the weight lost and corrosion rate of the metal in any given environment.

For this reason, this present study focused extensively on the experimental approach to examine the effects of physicochemical parameters of different environment on corrosion process as well as the activities and roles of micro-organisms in corrosion process in these environments.

2. MATERIALS AND METHODS

Sample Collection

Soil samples were collected from various zones of Cross Rivers State in Niger Delta area of Nigeria. These soils samples were transported into the Department of chemical/Petrochemical Engineering Laboratory of Rivers State University Port Harcourt for analysis on the physicochemical parameters. For the purpose of microbial isolation, identification and characterization some of the soil samples were transported into the Department of Microbiology and Department of Soil Science for purpose of soil characterization all in the Rivers State University Port Harcourt. The experimental soils used for this study include swampy, clay and sandy and the various soil samples were collected from Cross-River. Microbial identification and isolation as well as the physicochemical properties of the experimental soils were determined in the Department of Microbiology and Soil Science Laboratory, Rivers State University, Port Harcourt.

Materials

Materials used for this study include: swamp soil, clay soil, sandy soil, mild steel, carbon steel, copper steel and stainless steel as well as the materials useful in sampling the physicochemical and bacteriological properties. The parameters analyzed in this investigation are temperature, pH, and conductivity, total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand, moisture content, density etc

Determination of Corrosion Rate of Metals

Procedure

The metals were purchased from mile 3 mechanic workshops and then cut to sizes as well perforated. The various metals were transported to the Department of Chemical/Petrochemical Engineering, Rivers State University Port Harcourt for onward setting of the full experiment. The various pieces of metals were measured from the dealers for the purpose of this research work. 5gram of the various soil samples were measured and introduced into the various containers and then the metal specimens were immersed

into the various soils. The metal was scrubbed with iron brush and sand papered to remove the corroded scale and increase the degree of smoothness of the surface. The cleaned metal was swashed with detergent and rinse with acetone for easy drying.The various dried metals were measured in terms of thickness, length, width weight and breadth as well labeled. The perforated areas were tied with marine rope and before then the metal specimens was buried metal for period of time before exhumed after 30 days from their various containers. All substance was removed and metals weigh to the weight loss which was used in the calculation of the corrosion rate. The metals were also buried into their respective containers for another 30 days for further test. This was done for 10th June – 2018 11th June 2019.

Corrosion rate calculation

$$CR(Mpy) = \frac{W \ x365}{AxDxT} \ x1000$$

Where, W = weight loss. A = area, D = density and T = time.

Figure 1 Map of Cross Rivers State

Figure 1 illustrates the map of Cross Rivers State located in Niger Delta area of Nigeria, where the soil samples were collected for purpose of studying the effect of their soil characteristics on the metal corrosion.

3. RESULTS AND DISCUSSION

The results obtained from the research work are presented in Figures

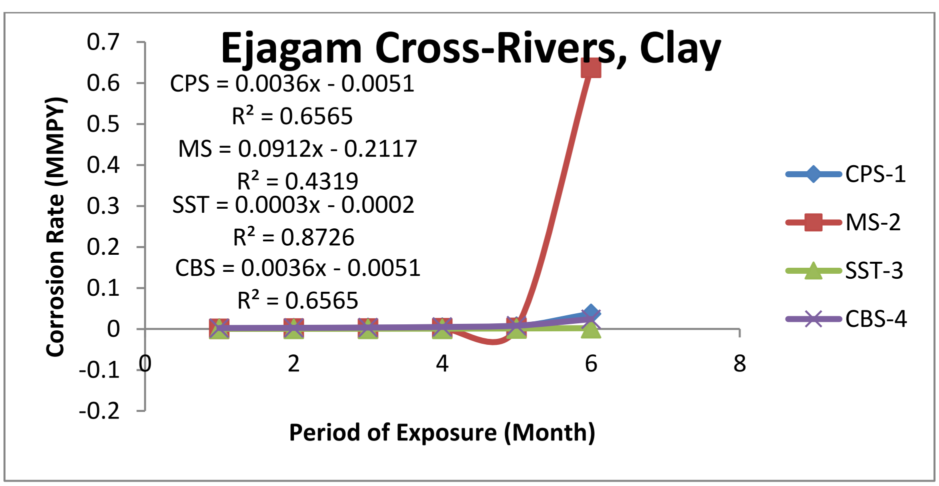

Figure 2 Corrosion Rate versus Period of Exposure for Clay Soil in Ejagam

Figure 2 demonstrates the relationship between that corrosion rate of various metals sampled and the period of exposure for clay soil sample of Ejagam community in Cross River State. Increase in corrosion rate was obtained with increase in period of exposure. The increase in corrosion rate in the day soil of Ejagam community can be attributed to the physiochemical properties of the soil. The result obtained revealed variation in the concentration of the physiochemical parameters or properties of the soil to metal interaction as metals loss it weight. The activities of the microorganisms isolated, identified and characterized from the various samples containers revealed the contribution of microbial action on metal corrosion. The variation on metal corrosion can be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period of exposure is expressed as CPS = 0.0036x – 0.0051 with the square root of the best fit given as R^2 = 0.6565 for MS = 0.0912x – 0.247 with square root of R^2 = 0.4319, for SST = 0.0003x – 0.0002 with square root of R^2 = 0.8726 and CBS = 0.0036x – 0.0051 with square root of R^2 = 0.6165.

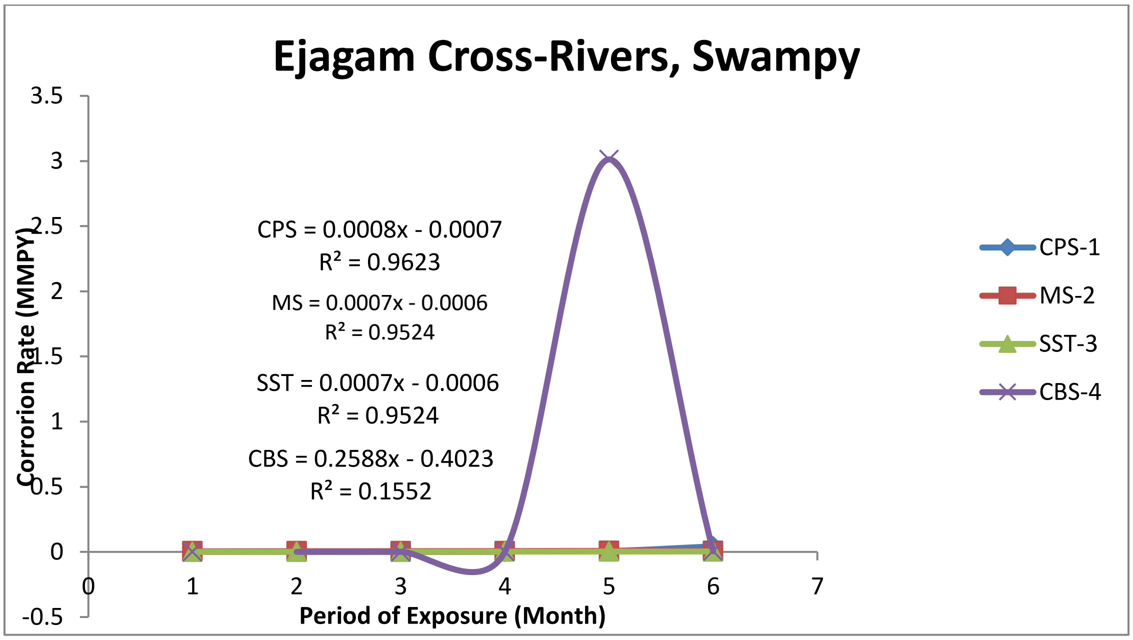

Figure 3 Corrosion Rate versus Period of Exposure for Swampy Soil in Ejagam

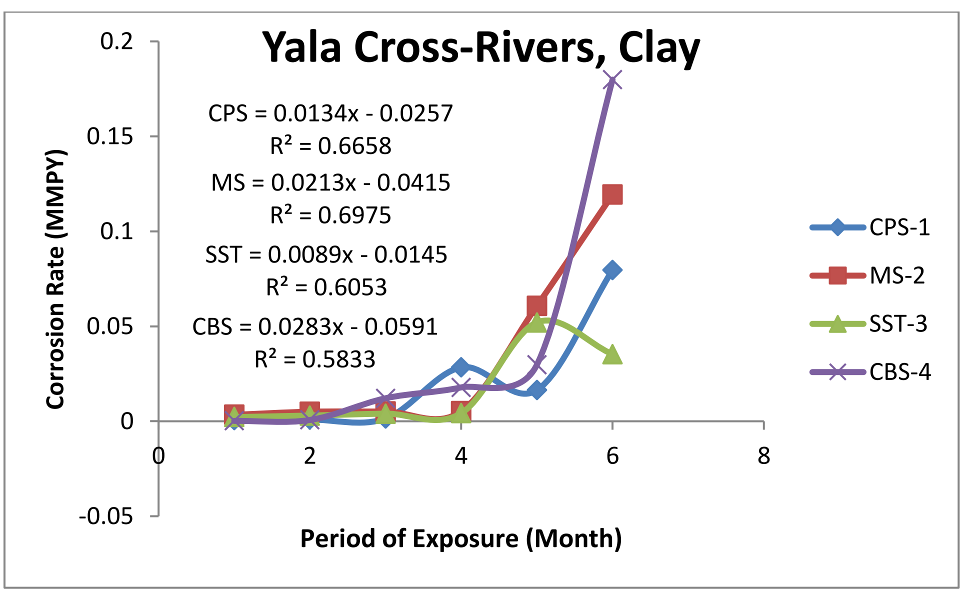

Figure 4 Corrosion Rate versus Period of Exposure for Clay Soil in Yala

Figure 3 depicts the relationship between the corrosion rate of various metal sampled and the period of exposure for swampy of Ejagam in Cross Rivers State. Increasing corrosion rate was observed with increase in period of exposure. The increase in corrosion

rate in the swampy soil sample of Ejagam community could be as a result of the physicochemical properties of the soil. The results obtained revealed variation in the concentration of the physicochemical parameters or properties of the soil to metal interacted as the metals losses it weight. The interactions of the microorganisms isolated, identified and classified from the various vessels where the metals were analyzed revealed the impact of contribution of microbial action on metal corrosion. The variation on metal corrosion could be as result of the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period of exposure is expressed as: for CPS = 0.0006x – 0.007 with square root of the best fit of R^2 = 0.9623, for MS = 0.0007x – 0.0006 with square root R^2 = 0.9524, for SST = 0.0007x – 0.0006 with square root R^2 = 0.9524, for CBS = 0.2588x – 0.4023 with square root of R^2 = 0.1552. The above result depicted a reliability or acceptability of 96.23% for CPS, 95.24% for MS, 95.24% for SST and 15.52% for CBS. Figure 4 illustrate the relationship between the corrosion rate of various sample of metals and the period of exposure for clay soil sample of Yala community in Cross Rivers State. It was observed that increase in corrosion rate lead to corresponding increase in the period of exposure. The increase in corrosion rate on the clay soil of Yala community can be attributed to the physicochemical properties of the soil. The results obtained depict variation in the concentration of the physicochemical properties of the soil to the metal information of the metals losses weight. The activity of the microorganisms isolated, identified and characterized from the various vessels where the metals are analyzed revealed the contribution of microbial action in metal corrosion. The variation on metal corrosion can be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained from each metal corrosion on the influence of the period of exposure is expressed as CPS = 0.0134x – 0.0257 with the square root of best fit given as R^2 = 0.658 for Ms = 0.0912x – 0.2117, R^2 = 0.4319 for SST = 0.0003x – 0.0002, R^2 = 0.8726 for CBS = 0.0036x – 0.0051, R^2 = 0.6565. The result obtained depicted 66.58% for CPS, 69.75% for MS, 60.53 for SST and 58.33% for CBS reliability or acceptability respectively.

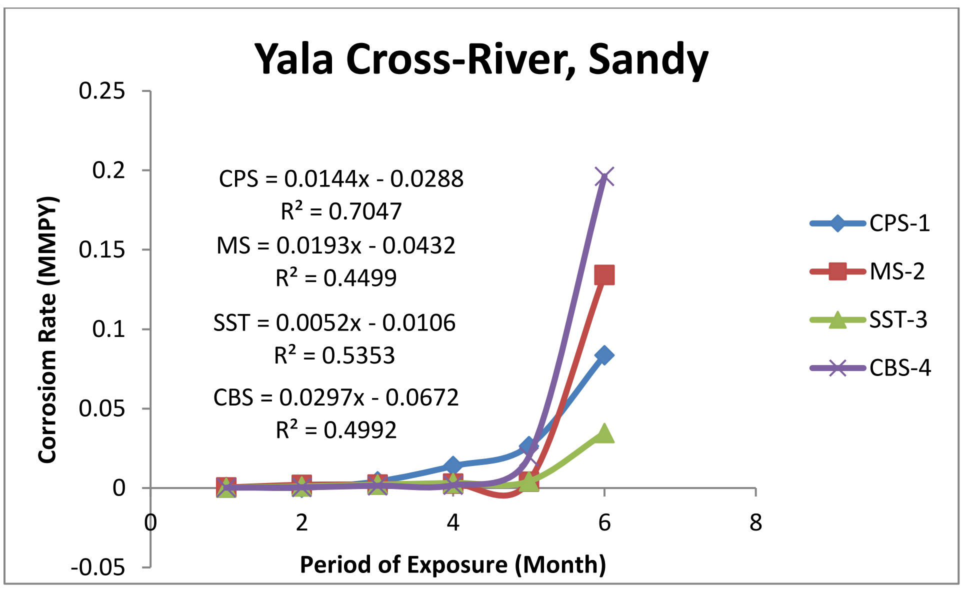

Figure 5 Corrosion Rate versus Period of Exposure for Sandy Soil in Yala

Figure 5 depicts the relationship between the corrosion rate of various metals and the period of exposure for sandy soil samples of Yala community in Cross Rivers State. It critically observed that as the corrosion rate increases the period of exposure also increases. The increased in corrosion rate could be attributed to the physiochemical parameters of the soil sample. The results obtained revealed variation in the concentration of the physicochemical parameters of the soil to metal interaction as the metals losses weight. The activities of the microorganisms identified and analyzed from various containers revealed the contribution of microbial action on metal corrosion. The variation on metal corrosion could be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period of exposure as expressed as: for CPS = 0.0140x - 00288 with square root of best fit given as R^2 = 0.7047 for MS = 0.0193x – 0.0432 with square root of R^2 = 0.4499 for SST = 0.0052x – 0.0106 with square root of R^2 = 0.5353, for CPS = 0.0297x – 0.0692 with square root of R^2 = 0.4992. From the above it depicted a reliability of acceptability of 70.47% for CPS 44.99% for MS, 63.53% for SST and 49.92% for CBS.

Figure 6 illustrates the relationship between the corrosion rate of various metals analyzed and the period of exposure for clay soil sample of Yala community in Cross Rivers State. It was observed as the corrosion rate increases the period of exposure also

increases. The increase on corrosion rate in the clay soil of Yala community could be attributed to the physicochemical properties of the soil. The result obtained revealed variation in the concentration of physicochemical parameters or properties of the soil to metal interaction as the metals losses it weight. The activities of the microorganisms which was isolated, identified and characterized from various vessels where the metal were supplied revealed the contribution of microbial action on metal corrosion. The variation on metal corrosion could be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period exposure is expressed as: for CPS = 0.0063x – 0.013 with square root of the best fit given as R^2 = 0.5308, for MS = 0.0062x – 0.012 with square root of R^2 = 0.5208, for SST = 0.0064x – 0.013 with square root of R^2 = 0.5208, for CBS = 0.4559x – 0.7085 with square root of R^2 = 0.178. The above result showed a reliability or acceptability of 53.08% for CPS, 52.08%, for MS 52.08%, for SST and 17.8% for CBS.

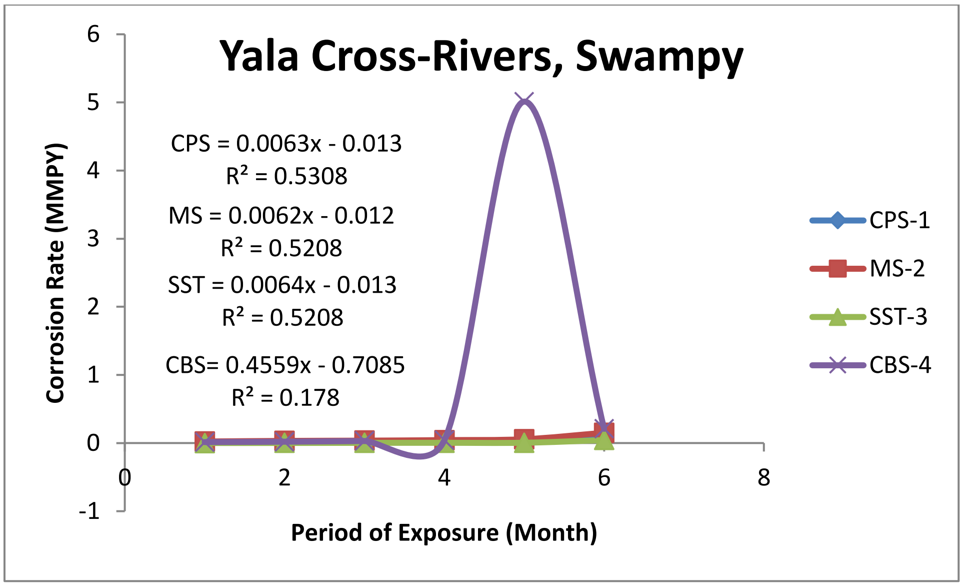

Figure 6 Corrosion Rate versus Period of Exposure for Swampy Soil in Yala

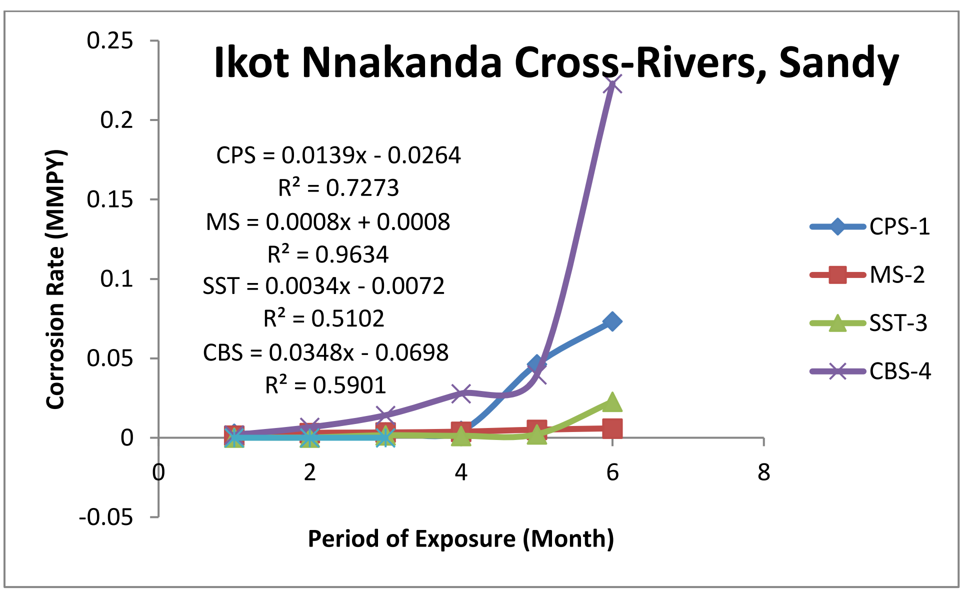

Figure 7 Corrosion Rate versus Period of Exposure for Sandy Soil in IkotNnakanada

Figure 7 demonstrates the relationship between the corrosion rate of various metals and the period of exposure for sandy soil sample of IkotNnakanda community in Cross Rivers State. Increase in corrosion rate was observed with increase in period of exposure. The increase in corrosion rate in the sandy soil of Nnakanda community could be attributed to the physicochemical properties of the soil. The result obtained revealed variation in the concentration of the physicochemical parameters of the soil to

metal interaction as the metals losses weight. The activities of the microorganisms isolated and characterized from the various containers revealed the microbial action on metal corrosion. The variation on metal corrosion could be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period of exposure is expressed as: CPS = 0.0139x – 0.0264 with square root of best fit R^2 = 0.7273, for MS = 0.0008x + 0.0008 with square root R^2 = 0.9634 for SST = 0.0034x – 0.0072 with square root of R^2 = 0.5102 and for CBS = 0.0348x – 0.0698 with square root of R^2 = 0.5901.

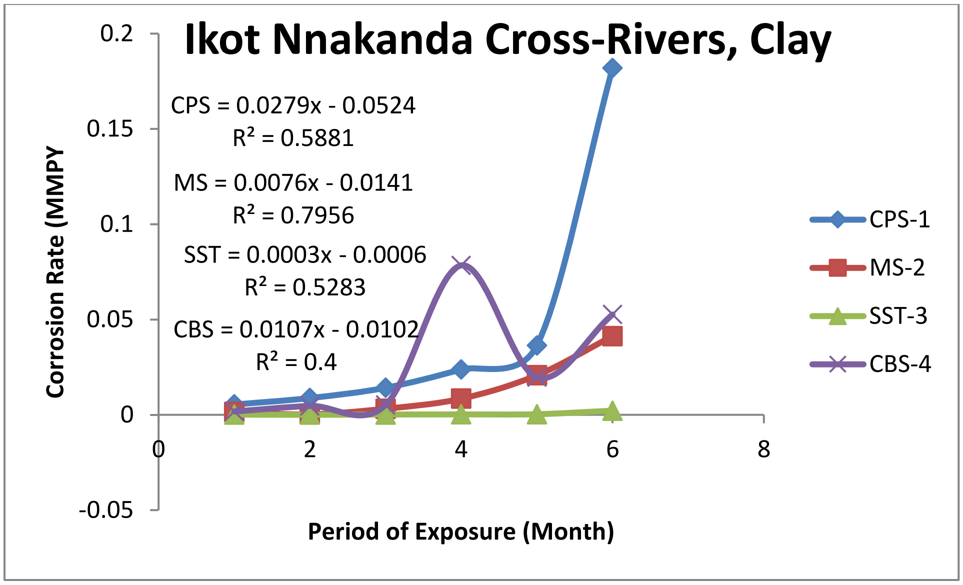

Figure 8 Corrosion Rate versus Period of Exposure for Clay Soil in IkotNnakanada

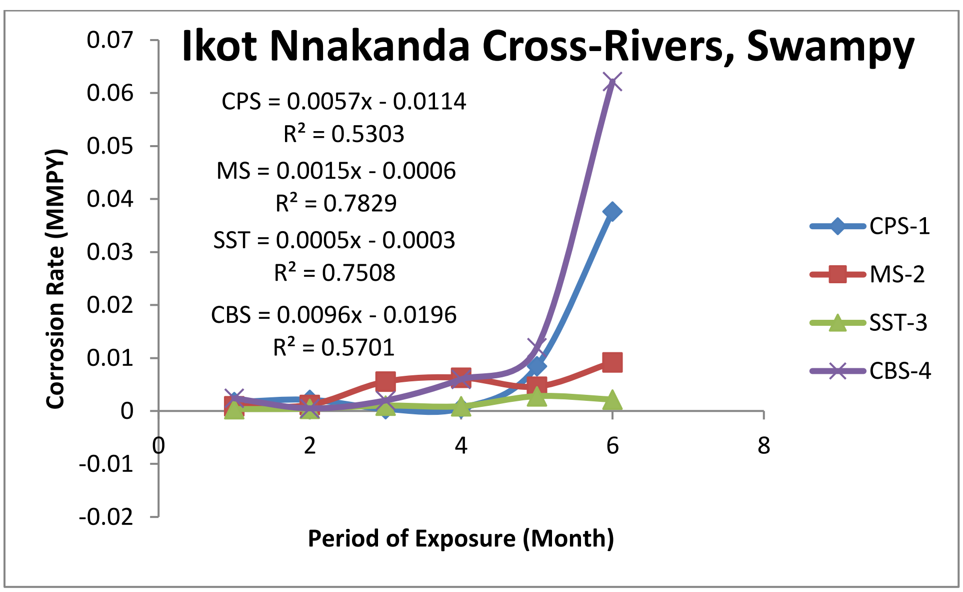

Figure 9 Corrosion Rate versus Period of Exposure for Swampy Soil in IkotNnakanada

Figure 8 shows the relationship between the corrosion rate of various metals and the period of exposure for clay soil sample of IkotNnakanda community in Cross Rivers State. It was observed as the corrosion rate increases the period of exposure also increases. The increase in corrosion rate was attributed to the physicochemical properties on parameters of the soil. The result obtained revealed variation in the concentration of the physicochemical parameters of the soil to metal interaction as the metals losses weight. The activities of the microorganism isolated, identified and characterized from the various vessels where the metals were analyzed revealed the contribution of microbial action on metal corrosion. The variation on metal corrosion could be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal

corrosion on the influence of the period of exposure is expressed as: for CPS = 0.0279x – 0.0524 with square root of the best fit given as R^2 = 0.5881, for MS = 0.0076x – 0.0141 with square root of R^2 = 0.7956, for SST = 0.0003x – 0.0006 with square root of R^2 = 0.5283 and for CBS = 0.0107x – 0.0102 with square root of R^2 = 0.4. A result of the reliability or acceptability for each of metal corrosion was obtained as 58.81% for CPS, 79.56% for MS, 52.83% for SST and 40% for CBS.

Figure 9 illustrates the relationship between the corrosion rate of various metals analyzed and the period of exposure for swampy soil sample of IkotNnakanda community in Cross Rivers State. From the figure it was observed that as the corrosion rate increases, the period of exposure also increases. The increase in corrosion rate in the swampy soil of IkotNnakanda community could be attributed to the physicochemical parameters or properties of the soil to the metal interaction as the metals losses it weight. The activities of the microorganisms separated identified and characterized from the various cylinders where the metals were sampled revealed the concentration of microbial action on metal corrosion. The variation on metal corrosion could be attributed to the variation on the period of exposure which induced the environment. The equation of the curve obtained for each metal corrosion on the influence of the period of exposure is expressed as: CPS = 0.0057x – 0.0114 with square root of the best fit given as R^2 = 0.5803, for MS = 0.0015x – 0.0006 with square root of R^2 = 0.7829, for SST = 0.0005x – 0.0003 with square root of R^2 = 0.7508, for CBS = 0.0096x – 0.0196 with square root of R^2 = 0.5701. The above results depicted a reliability or acceptability of 53.03% for CPS, 78.29% for MS, 75.08% ST and 57.01% for CBS.

4. CONCLUSION

The following conclusion was drawn from this research work:

The variation in soil physicochemical parameters is one of the significant factors identified as major agent of corrosion on the various metals sampled. The present of the microbes identified and isolated was discovered to be other major contributing factors to the corrosion of the various metals studied. High corrosion rate was observed in the various metals specimen in the order of swampy soil environment followed by clay soil and lastly the sandy soil environment. Metals to be buried underground in this region of the Cross Rivers State needs adequate protection by the required coating materials to prevent constant failures. The study also reveal that the metal corrosion in faster in both dry and wet season base on the characteristics of the physicochemical concentration of the soil environment.

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Conflicts of Interest: The authors declare no conflict of interest.

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